11. Comparing WAsP and Fluent for highly complex terrain wind prediction

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11.1 INTRODUCTION

Assessing wind conditions on complex terrain has become a hard task as terrain complexity increases. That is why there is a need to extrapolate in a reliable manner some wind parameters that determine wind farms viability such as annual average wind speed at all hub heights as well as turbulence intensities.

The development of these tasks began in the early 90´s with the widely used linear model WAsP and WAsP Engineering especially designed for simple terrain with remarkable results on them but not so good on complex orographies. Simultaneously non-linearized Navier Stokes solvers have been rapidly developed in the last decade through CFD (Computational Fluid Dynamics) codes allowing simulating atmospheric boundary layer flows over steep complex terrain more accurately reducing uncertainties.

This paper describes the features of these models by validating them through meteorological masts installed in a highly complex terrain. The study compares the results of the mentioned models in terms of wind speed and turbulence intensity.

11.2 ALAIZ TEST SITE

Alaiz hill is 4 kilometers long, 1050 meters high a.s.l. and is surrounded by a complex terrain associated to a ruggedness index (RIX) of 16%. The roughness level is high since the hill is covered by dense forests whereas the area upwind is clear without remarkable roughness elements.

Three meteorological masts located on the hill were employed in the study (Alaiz2, Alaiz3 and Alaiz6) forming a one year data base composed by hourly wind speed and wind direction values. Direction analysis afforded two main prevailing sectors at north and south.

11.3. DESCRIPTION OF THE MODELS

11.3.1 Linear models. WAsP 8.1 (Wind Atlas Analysis and Application Program) and WAsP Engineering 2.0

The linear model WAsP developed by Risoe allows simulating wind behaviour by obtaining the so-called geostrophic wind atlas regime taking into account the effects of terrain variation, surface roughness and nearby obstacles at a local mast. The model, as it occurs with other linear models, is limited to neutrally-stable wind flows over low, smooth hills with attached flows [5][6].

The wind atlas offers the possibility to spatially extrapolate the wind statistics obtained at a certain meteorological mast to different hub heights at other locations. The program has been validated at different sites and widely used for assessing wind.

On the other hand, WAsP Engineering developed also by Risoe and introduced in 2001, simulates extreme wind, shear, flow angles, wind profiles and turbulence, being made as a complement of WAsP [3].

The purpose of WAsP Engineering is supporting the estimation of loads on wind turbines and other civil engineering structures in complex terrain.

11.3.2 Non linear models. Fluent 6.2

The Navier-Stokes solver Fluent 6.2 is one of the world’s leading CFD commercial packages widely validated for a huge variety of flows supporting different mesh types. This non-linearized solver permits to recognise detached flows and to obtain iteratively the velocity magnitude and its components, the static pressure and the fields of turbulent kinetic energy (TKE) and turbulence dissipation rate through the K-ε model. In this study, wind is considered a 3D incompressible steady flow in which Coriolis force and heat effects have been omitted so neutral state of the atmosphere is considered [7].

11.4 RESULTS

Validation was made by comparing the measuring campaign and the simulated wind speed and turbulence intensity from a horizontal and vertical extrapolation (for those values contained in the interval 350º - 10º) between the lower level at one mast and the higher levels at the rest.

11.4.1 Wind speed

The comparison shown in table 1 indicates that CFD extrapolates wind speed between masts more accurately in almost all cases giving an average absolute error of 1.75% significantly less than the others: 5.67% for WAsP Eng and 5.41% for WAsP.

11.4.2 Turbulence intensity

Table 1 also offers the comparison for turbulence intensity (TI) at the test site, which was carried out for WAsP Engineering 2.0 and Fluent 6.2.

As it is seen, both models obtained similar results when trying to extrapolate TI between masts. This result is also observed through the average absolute error: 36.79% for WAsP Engineering and 35.86% for Fluent.

The level of TI is not well captured by any of the studied models, being for CFD significantly lower than the measured values although the tendency was better modelled.

11.5 CONCLUSIONS

The analysis indicates that the non-linear solver Fluent 6.2 can simulate more accurately wind speed field for complex terrain than other wind flow models. Nevertheless, no conclusion could be extracted so far about which model explains better turbulence intensity.

Future works using CFD Fluent 6.2 will focus on testing more sophisticated turbulence models as well as on improving the distribution of surface roughness. Turbulence validation will be also done by means of more advanced wind sensors such as Lidar. On the other hand, grid independence studies will be carried out to reduce computing time.

These tasks will allow decreasing uncertainties in the near future when assessing wind farms power production in complex terrain.

This study has been carried out thanks to Alaiz wind farm data provided by Energía Hidroeléctrica de Navarra (EHN).

Table 1. Measurements and simulation results for wind speed and turbulence intensity

		WIND SPEED			TURBULENCE INTENSITY		
Input mast		**WAsP**	**WAsP Eng**	**Fluent**	**WAsP Eng**	**Fluent**	**Output mast**
	ΔV/ ΔTI	1.10	1.22	1.09	0.77	1.01	WS=8.96 m/s
	al3_30m	8.96	9.98	8.92	8.40	11.01	TI=12.62%
	Error (%)	0.02	11.41	-0.47	-33.43	-12.46	
	ΔV/ ΔTI	1.26	1.23	1.10	0.78	0.81	WS=9.08 m/s
al2_20m	**al3_40m**	10.31	10.03	8.96	8.57	8.86	TI=11.68%
	Error (%)	13.55	10.46	-1.36	-26.68	-24.21	
WS=8.15 m/s	ΔV/ ΔTI	1.27	1.23	1.11	0.80	0.34	WS=9.35 m/s
TI=0.93 %	**al3_55m**	10.37	10.05	9.04	8.72	3.71	TI=10.67%
	Error (%)	10.93	7.51	-3.28	-18.28	-65..21	
	ΔV/ ΔTI	1.15	1.13	1.04	0.90	0.30	WS=8.93 m/s
	al6_40m	9.39	9.18	8.46	9.82	3.30	TI=8.22%
	Error (%)	5.17	2.82	-5.19	19.38	-59.82	
al3_30m	ΔV/ ΔTI	0.84	0.86	0.93	1.28	0.52	WS=9.27 m/s
	Al2_40m	8.30	8.50	9.15	14.61	5.92	TI=7.55%
WS=9.38 m/s	Error (%)	-10.51	-8.35	-1.37	93.50	-21.64	
TI=11.38 %	ΔV/ ΔTI	0.92	0.92	0.95	1.17	0.30	WS=9.49m/s
	Al6_40m	9.02	9.06	9.36	13.35	3.41	TI=7.13 m/s
	Error (%)	-4.91	-4.49	-1.37	87.32	-52.07	
	ΔV/ ΔTI	0.95	0.96	1.00	1.12	0.67	WS=9.12 m/s
	Al2_40m	8.70	8.84	9.17	7.71	4.58	TI=9.99%
	Error (%)	-4.55	-3.02	0.57	9.01	-35.20	
	ΔV/ ΔTI	1.07	1.12	1.07	0.87	1.28	TI=9.85 m/s
al6_20m	**al3_30m**	9.85	10.26	9.88	6.01	8.82	TI=8.70%
	Error (%)	0.03	4.19	0.31	-39.83	-11.75	
WS=9.19 m/s	ΔV/ ΔTI	1.13	1.13	1.08	0.89	1.03	WS=9.99 m/s
TI=6.89 %	**al3_40m**	10.35	10.41	9.92	6.12	7.09	TI=8.70%
	Error (%)	3.60	4.20	-0.69	-29.58	-18.45	
	ΔV/ ΔTI	1.13	1.12	1.09	0.90	0.43	WS=10.3m/s
	al3_55m	10.40	10.34	10.02	6.22	2.97	TI=6.98%
	Error (%)	0.81	0.23	-2.90	-10.85	-57.44	
	Average	5.41	5.67	1.75	36.79	35.86	

Input mast/ Output mast = Wind speed and turbulence intensities measured at input and output masts.
ΔV/ ΔTI = Change in wind speed/turbulence intensity between masts.

References

[1] Ansys ICEM CFD 5.2 User Guide (2004), Ansys Inc.

[2] Fluent 6.2 User´s Guide (2005), Fluent Inc.

[3] Mann et al. (2002). WAsP engineering 2000. Risø-R-1356(EN) 90 p.

[4] Richards and Hoxey (1993): Appropiate boundary conditions for computational wind engineering models using the K-Eps turbulence model, Journal of Wind Engineering and Industrial Aerodynamics, vol 46&47, pp.145-153

[5] Bowen and Mortensen (1996). Exploring the limits of WAsP. The wind atlas analysis and application program. Proceedings of the 1996 EWEC (Sweeden).

[6] Troen and Lundtang (1989), European Wind Atlas Risø (Denmark)

[7] Villanueva et al. (2004): Wind Resource Assessment in complex terrain using a CFD model. Proceedings of the 2004 EWEA Special Topic Conference. Delft (The Netherlands)